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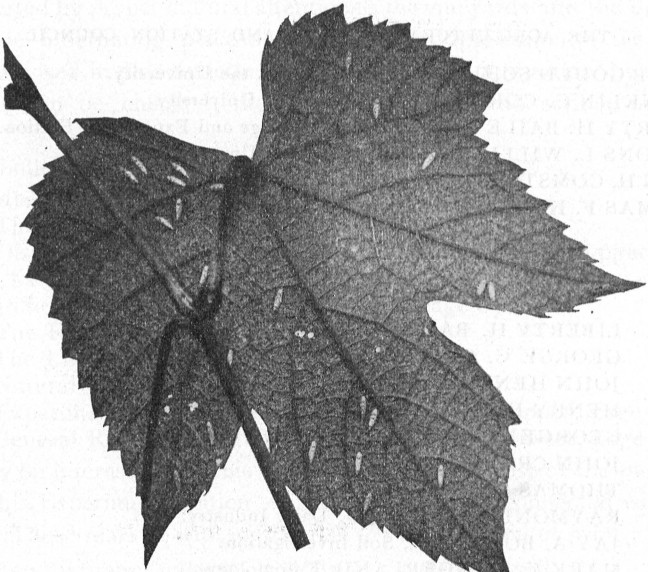
CORNELL UNIVERSITY
EXPERIMENT STATION OF
THE COLLEGE OF AGRICULTURE
Department of Entomology (Extension Work.)

THE GRAPE LEAF-HOPPER



By M. V. SLINGERLAND

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COLLEGE OF AGRICULTURE, CORNELL UNIVERSITY,
ITHACA, N. Y., Jan. 1, 1904.

HONORABLE COMMISSIONER OF AGRICULTURE, ALBANY.

Sir :—I submit herewith the results of a detailed study of the leaf-hopper of the grape, together with an account of experiments made by this Station in Chautauqua county to discover means of controlling it. The insect is one of that large class that usually comes into great economic prominence only at relatively long intervals in the same locality, although nearly always present in considerable numbers. When another serious outbreak may occur, no one knows, but to be forewarned is to be forearmed. The danger of attacks can be often largely averted by proper cultural attention to the vineyards and the destruction of favorable hibernating places. By the proper application of the remedial measures advised in this bulletin, the most serious infestation by the grape leaf-hopper can be checked, the insect controlled, and serious injury prevented.

This bulletin is divided as follows :

I. Historical notes, page 84.
II. The Name of the Insect, page 84.
III. Distribution and Destructiveness of the Grape Leaf-Hopper, page 85.
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VI. The Food-plants, page 88.
VII. The Life-History of the Insect, page 89.
VIII. Natural Checks and Enemies, page 95.
IX. Experimental Work against the Grape Leaf-Hopper, page 95.
X. General Recommendations for Combating the Insect, page 102.

It may be interesting, in this connection, to give a list of the publications made by this Experiment Station on subjects directly connected with grape-growing. Those marked with an asterisk (*) are now out of print.

* Fertilizers for Grape Cuttings. L. H. Bailey. Bulletin 49, 1892.
* Some Grape Troubles in Western New York. E. G. Lodeman. Bulletin 76, 1894.
* The Grafting of Grapes. E G. Lodeman. Bulletin 77, 1894.
* Geological History of the Chautauqua Grape Belt. R. S. Tarr. Bulletin 109, 1896.
Chemistry of the Soil and of the Grape. G. C. Caldwell. Bulletin 110, 1896.
Commercial Grape Culture in Chautauqua Co. S. S. Crissey and G. Schoenfeld. Bulletin 110.
Picking and Packing Grapes. J. A. Tennant. Bulletin 110.
Grapes, Development of Methods on Large Areas:
  Grape Growing in North Chautauqua. E. S. Bartholomew. Bulletin 110.
  Conditions of Climate Favoring the Grape. From Transactions of Chaut. Hort. Soc. Bulletin 110.
  Why I Sow Rye in the Vineyard. G. Schoenfeld. Bulletin 110.
* Spray Calendar. E. G. Lodeman. Bulletin 114, 1896.
* Packing Houses for Fruit. L. H. Bailey. Bulletin 117, 1896.
The Grape-Vine Flea Beetle. M. V. Slingerland. Bulletin 157, 1898.
The Grape Root-Worm. M. V. Slingerland. Bulletin 184, 1900.
Spray Calendar. Bulletin 188, 1901.
The Grape Root-Worm: Further Experiments and Cultural Suggestions. M. V. Slingerland and John Craig. Bulletin 208, 1902.

Respectfully submitted,
L. H. BAILEY, Director.

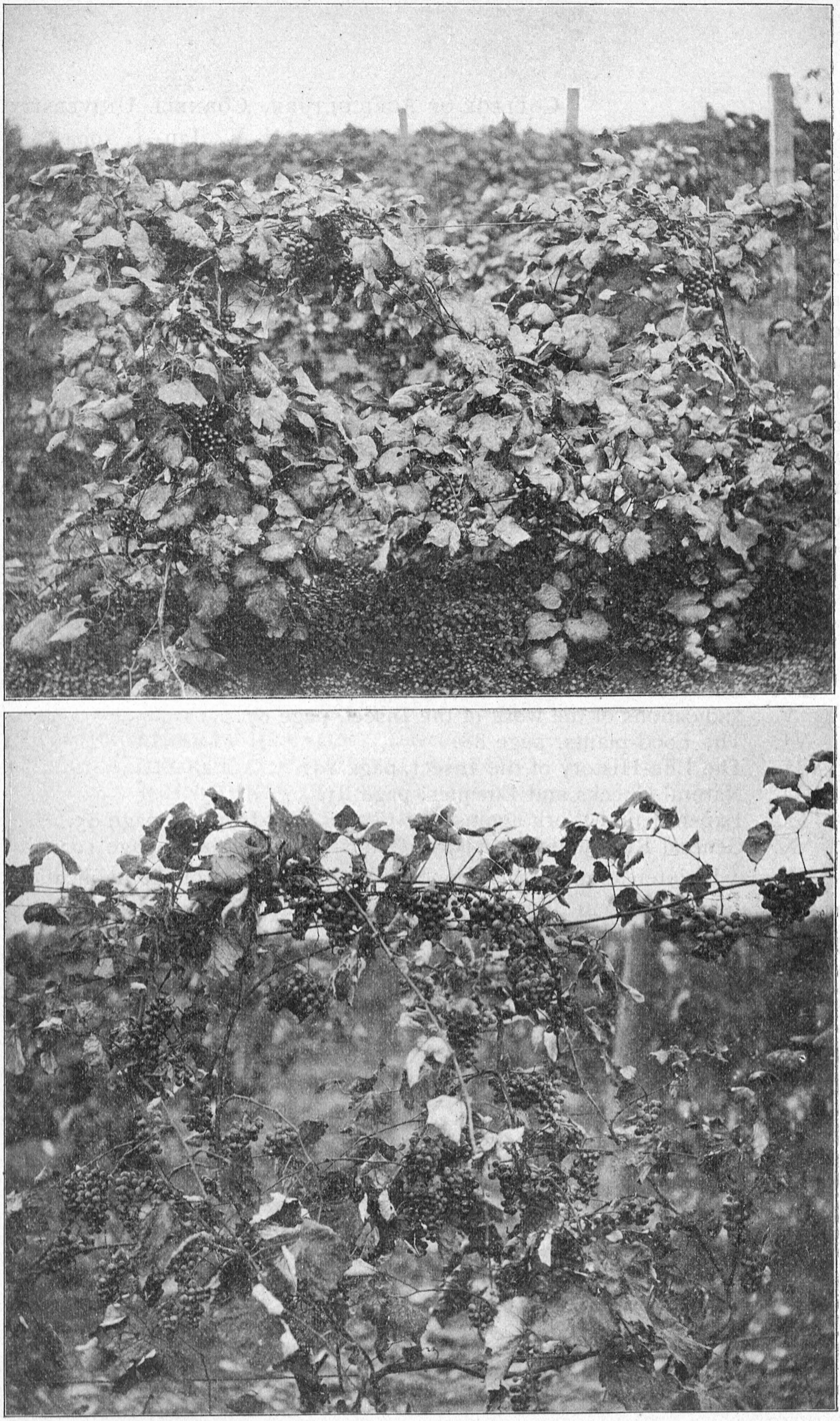

FIG. 37.—*Sprayed (above) and unsprayed vines in neighboring vineyards. The leaf-hoppers killed the leaves on the lower vine, and the large crop of fruit and some of the*

THE GRAPE LEAF-HOPPER

Typhlocyba comes Say

Order HEMIPTERA; family JASSIDÆ

The grape leaf-hopper is our most common and widespread insect pest of the grape-vine. Practically every vineyard in the United States and Canada is infested by the insect, and almost every year it occurs in injurious numbers in one or more localities. It has its periods of great destructiveness and of comparative obscurity, or its "ups and downs," like most of our insect pests.

It was late in July, 1901, when we first learned of an extensive outbreak of this insect in Chautauqua county. The seriousness of the situation was not fully realized until it was too late to devise and test methods for checking it that season. Early in autumn it was evident that several hundred acres of vineyards in and near Westfield would be seriously injured and the crop much reduced. A few vineyards had suffered severely the year before, but no such extensive and destructive outbreak as that of 1901 had ever occurred in any of the great vineyard districts of New York. The crop was reduced more than one-half and it did not fully ripen in many cases, while the vines made but little growth, resulting in a great scarcity of wood to put up for the next season's growth. The adult "hoppers" swarmed everywhere; "the air was full of them," as some expressed it, late in the autumn, and millions of them went into hibernation that year.

The prospects for 1902 were certainly very alarming in the infested region and this Experiment Station determined to make a desperate fight against the insect. An extensive plan of campaign was mapped out during the winter, which the appropriation from the State for extension work enabled us to carry out during 1902. The fight was long, discouraging at times, and expensive in time and money, but striking success at last crowned the efforts.

The insect appeared in increased numbers and devastated more than a thousand acres of vineyards in 1902. The author with Professor Craig and two Cornell agricultural students, Messrs. G. A. Bell and G. W. Hosford, spent most of the summer in the infested region, personally conducting experiments and studying the life-history of the pest. The personal work among the vineyardists and the striking results of work in the treated vineyards gave the grape-growers new courage and many were ready to follow the methods and give the "hoppers" a hard fight the next season.

We learned many new facts in the life-story of the insect, but most of the work was experimental. Methods previously recommended were tested, and we devised and tried many new schemes for circumventing the "hoppers." The situation demanded wholesale measures and the chief difficulties were in devising practicable methods for successfully treating such extensive infested areas. Through frequent contributions to *The Grape Belt*, we kept the grape-growers advised of the progress of our work, and a brief circular giving directions for fighting the pest was distributed throughout the infested region last spring. The results of the work would have been published a year ago had not serious illness prevented, but the delay has enabled us to supplement and verify the work with another season's observations.

I. HISTORICAL NOTES

The grape leaf-hopper seems to have been first recorded from Missouri in 1825 when it was named and described. Soon afterward it was first discussed in horticultural literature[*] as a serious pest in Massachusetts, some growers having "abandoned their vines in consequence of its depredations." During the next decade, the insect was scarcely noticed in the literature, then Harris's classic account appeared in 1841.[†] Little was recorded during the next decade, but since 1855, it has been reported as injurious somewhere in the country nearly every year. For more than half a century, practically nothing new was added to Harris's story of the insect.

In nearly all discussions of the insect enemies of the grape during the past seventy-five years, the grape leaf-hopper has been put in the front rank with the most destructive ones. The records show that it has deserved a prominent place in the rogue's gallery of grape pests in Massachusetts since 1828, in New York since 1856, in Illinois since 1863, in Pennsylvania since 1865, in Connecticut and Maine since 1867, in Canada since 1871, in Michigan and California since 1875, in Ohio since 1888, and in New Mexico, Colorado, North Carolina and Minnesota since 1890. Destructive local outbreaks have also occurred in other states.

II. THE NAME OF THE INSECT

Scientific name.—That famous American entomologist, Thomas Say, first described and named this grape leaf-hopper, *Tettigonia comes*, in 1825[‡], or shortly before it was recorded as a pest. It sometimes presents such striking variations in its markings and coloration that at least six times it has been described as a distinct species. Nine distinct and quite sharply defined varieties of this species are now recognized, and it is put in the genus *Typhlocyba*,[§] probably meaning "blind-headed," as there are said to be no functional ocelli or simple eyes in the members of this subfamily of insects.

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[*] Fessenden's New American Gardener, Boston, 1828, p. 299; and Harris's Correspondence, p. 86 in Letter to Hentz in 1829.

[†] Harris's Report on Insects of Massachusetts Injurious to Vegetation, Boston, 1841, p. 183–185.

[‡] Journal Academy of Natural Sciences of Philadelphia, IV, 327.

[§] Synonomy of the grape leaf-hopper (from Gillette, in Proc. U. S. Nat. Museum, 1898, Vol. XX., p. 759–764):

Typhlocyba comes Say 1825.
vitifex Fitch. 1856.
Var. *basilaris* Say. 1825.
affinis Fitch. 1851.
Var. *vitis* Harris. 1831.
Var. *ziczac* Walsh. 1864.
Var. *octonotata* Walsh. 1864.
Var. *coloradensis* Gillette. 1892
Var. *maculata* Gillette. 1898.
Var. *scutellaris* Gillette. 1898.
Var. *rubra* Gillette. 1898.
Var. *infuscata* Gillette. 1898

Improperly called "thrips."—During the early outbreaks of this insect seventy-five years ago, the vineyardists called these little creatures "vine-fretters," an old common name for the plant-lice or aphids which infest the vine in Europe. In 1841, Harris proposed that these leaf-hoppers be called "vine-hoppers." Very soon, however, they were called "thrips,"* and in spite of frequent protests this name has clung tenaciously to the literature, and has doubtless been in more common use than any other. The name properly belongs to another group of much smaller insects known to science as *Physopoda*, none of which are injurious to the grape; a familiar species is that serious pest, the onion thrips. At last this unfortunate name of "thrips" for this grape pest is being superceded by the more proper one of "grape leaf-hoppers," which New York vineyardists shorten to "hoppers."

III. DISTRIBUTION AND DESTRUCTIVENESS OF THE GRAPE LEAF-HOPPER

The grape leaf-hopper is a native American insect and is one of the most common and widely distributed insect pests in the United States and Canada. There is scarcely a vineyard from coast to coast that does not suffer more or less from this little foe every year. During the past two or three years, it has been unusually numerous and destructive in New Jersey, New York, Ohio, Oklahoma, Colorado and California.

In New York.—The first authentic record of the grape leaf-hopper as a pest in New York is in 1856.† There is an earlier but somewhat doubtful record.‡ Since then, at frequent intervals, vineyards in various parts of the state § have been seriously injured by the insect.

The Chautauqua county outbreak.—The recent infestation of Chautauqua vineyards is the most serious and extensive that ever occurred in the State. While the leaf-hoppers have infested this grape region in noticeable numbers every year for many years, the older grape-growers say that never before has the pest done so much damage as during the past three years. Westfield is the centre of the seriously infested area which is about a mile wide and extends from near Ripley to Brocton, covering more than a thousand acres of vineyards.

The insect began its "up" or destructive period in this region in 1900 when but a few vineyards suffered noticeably. The climax was reached, or its most destructive work was done, in 1901 and 1902. While the "hoppers" were very numerous and did considerable damage in 1903, it was evident that the life pendulum for the insect had begun its "down" beat, which we hope will swing it into comparative obscurity as a pest for many years in Chautauqua county.

What the conditions were that brought about this serious outbreak of leaf-hoppers in this grape belt, are not apparent. Several writers have recorded that dry seasons are especially favorable for them and this may have been what gave the insects a start in 1900, but they throve mightily during the extremely wet season of 1902. When grapes brought very low prices a few years ago, many neglected their vineyards, allowing them to grow full of grass and weeds. Such vineyards furnished ideal hibernating conditions for the "hoppers." We believe this had much to do in starting this unprecedented outbreak. As grape leaf-hoppers have but few enemies, their periods of increase and decrease are doubtless also largely influenced by unknown weather conditions, especially during the six months or more when they are in hibernation.

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*Allen's Practical Treatise on the Grape-vine, p. 132, Boston, 1843.

† Fitch's Third Report on Insects of New York, 1856, p. 391, 392.

‡ Downing's Horticulturist, III., p. 28, article on Two Insects that infest the Native Grapes, by "C," New York, 1848.

§ In Wyoming county in 1860; in the Hudson Valley in 1865, 1867, 1882, 1887 and 1897; on Crooked Lake in 1880; in Jefferson county in 1887 and 1888; in Central New York in 1895 and 1899; and in Chautauqua county in 1900 to 1904.

European notes.—Although two closely allied kinds of leaf-hoppers infest the grape-vine in Europe, their injuries are usually insignificant.* One species, *flavescens*, occurs all over temperate Europe but has been recorded as a serious pest only in the vineyards of Algeria and Tunis in northern Africa. The other species, *viticola*, lives in Italy and on the islands of Elba and Pianosa off the western coast where it has sometimes done considerable injury.

Its destructiveness.—As early as 1829, Harris ranked the grape leaf-hopper next to the rose-chafer in destructiveness in Massachusetts, and for many years it has been called one of the worst or most formidable grape pests in this country. It infests most of our vineyards annually with great regularity, and the aggregate yearly loss to American grape-growers must be great. Nearly every year outbreaks occur over small areas in several different localities. The leaves are badly injured or killed, thus either reducing the crop or preventing its proper ripening, and the vines often make insufficient new growth to furnish the desired wood to tie up for the next year's crop. The destruction rarely, if ever, continues until the death of the vine results.

In 1901 and 1902 the "hoppers" were so numerous in some vineyards in Chautauqua county that they stunted or checked the growth early in the season and thus reduced the crop more than one-half (Fig. 19). Usually parts of vineyards near woods or other good "hopper" hibernating places suffered most from their ravages. In many vineyards the foliage was so badly injured that it turned brown and died prematurely, thus preventing the proper coloring, ripening and sweetening of the fruit. (Note comparison in Fig. 37). In 1901, when there was less rainfall, the ripening fruit was badly smutted or stained, probably by the excrement of the multitudes of adult "hoppers." The money loss to the grape-growers in the infested region would aggregate many thousands of dollars, and it will take a year or two to bring the vines back to their normal thriftiness in many cases.

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* The two species are known as *Typhlocyba flavescens* Fabr. and *Typhlocyba viticola* Targ. References: Mayet's Insectes de la Vigne, p. 167 (1890); Leonardi's Gli Insetti Nocivi, vol. 4, p. 161 (1901); Nuove Relazioni R. Stazione di Entomologia Agraria di Firenze, Serie Prima, No. 4, p. 451 (1902).

IV. CHARACTERISTICS OF THE INSECT

The principal characteristics of the grape leaf-hopper are well shown in the drawings in Figs. 16 and 18, and especially in the pictures from life in Figs. 17, 24 and 25. These leaf-hoppers, like their near relatives the plant-lice, scale insects, and cicadas, eat only liquid food which they suck with little beaks from the plants, much like a mosquito sucks our blood. As the pictures show, they are minute creatures, scarcely an eighth of an inch long, and their back and wings are peculiarly marked with yellow and red. In summer, the young and adult insects are light yellowish in color, but before going into hibernation, the eyes of the adults darken and the peculiar yellow spots on the wings change to an orange-red, thus giving the hibernating adults a general reddish appearance. These darker markings on the adults vary so much that nine very distinct varieties of the insect are now recognized; two are represented at *b* and *c* in Fig. 16. Often several of the varieties may be found together on the same vines, but usually one color-form largely predominates.

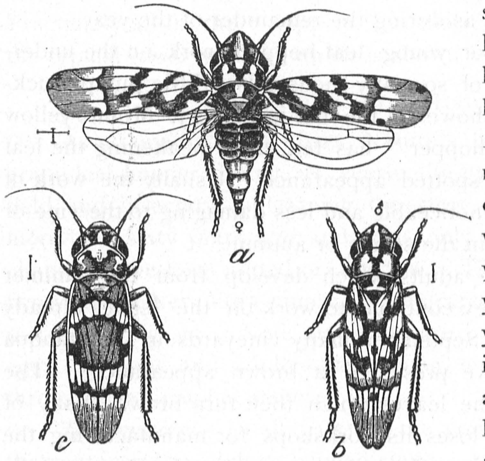

FIG. 16.—*Adult grape leaf-hoppers much enlarged; a and b are female and male of the typical* comes *variety; c represents the* vitis *variety.*

The young insects or *nymphs* are shown natural size and enlarged in Figs. 18 and 24. They are of a light yellowish-green color with lemon-yellow stripes on each side the body. In growing they pass through the five different stages shown in the "life-cycle" Fig. 15, their little wing-pads gradually getting larger.

There are no other insect pests that infest the grape-vine which in any way resemble these leaf-hoppers, so vineyardists can easily recognize them.

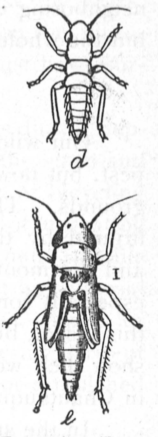

FIG. 18.—*Two nymph stages of the grape leaf-hopper, much enlarged.*

V. INDICATIONS OF THE WORK OF THE INSECT

When the grape leaf-hoppers occur in injurious numbers, their activity in leaping and flying from the vines in swarms at the least disturbance often reveals the presence of the pest before its destructive work is noticed. Soon after the first lower leaves of the vine appeared, or during the latter half of May in western New York, the old or hibernated "hoppers" swarmed on to the vines and in two or three weeks the new growth was checked, and the leaves curled and turned brown in spots, finally resulting in considerably lessening the set of fruit. In Fig. 19 is shown three shoots (on the right) from a badly injured vineyard contrasted with two uninfested shoots. The two leaves in the upper part of Fig. 20 show how the adult "hoppers" curl and "brown" the leaves in the spring. Often fully as much damage is done by this insect on the new growth early in the season as during the remainder of the year.

In midsummer the nymphs or young leaf-hoppers work on the undersides of the leaves; and the result of so many thousands of little pumps sucking out the interior tissues is well shown on the leaf in Fig. 23. Minute yellow spots appear wherever a little "hopper" has fed, thus weakening the leaf and giving it quite an unnatural, spotted appearance. Usually the work of the nymphs in the summer is less noticeable and less damaging to the vine or fruit than that of the adult insects in the spring or autumn.

During August and later, the adults which develop from the summer nymphs are very destructive. They continue to work on the leaves already weakened by the nymphs; and by September many vineyards in Chautauqua county in the past three years have presented a brown appearance. The "hoppers" suck the life from the leaves which then turn brown, many of them drop off, and thus the vine loses its workshops for manufacturing the sweetness that goes into the fruits. In consequence, the fruit never fully ripens, remains reddish in color, and is noticeably lacking in flavor and sweetness. The fruit is often badly smutted or stained in the fall, probably from the excrement of the "hoppers." This destructive work of the pest in the autumn is well contrasted in the pictures shown in Fig. 37 of vines from neighboring vineyards. The "hoppers" work only on the leaves of the vine, but the whole vine and its fruit suffer from their ravages.

VI. THE FOOD-PLANTS

Our wild grapes were doubtless the natural food of this American grape pest, but now man's cultivated varieties usually furnish their favorite feeding grounds. The Ampelopsis or Virginia creeper vine also has been seriously injured by the insect in Colorado, Minnesota, Canada, northern New York and Vermont; the variety of this leaf-hopper known as *ziczac* seems to be especially fond of this vine. No variety of grape is exempt from attack by this insect, but the thinner-leaved varieties, as Clinton and Delaware, often show their work first. Whole Concord vineyards have been devastated by it in Chautauqua county.

In the spring before the grape foliage is out sufficiently, the hibernated adult insects attack almost any plant near vineyards. In April and May in Chautauqua county they noticeably injured neighboring strawberries, raspberries and dewberries, and also young, tender beech trees and other small plants in the woods where they hibernated. In Colorado these old "hoppers" have worked on currants, gooseberries, alfalfa, grass, and some other native plants before the grape leaves were large enough ; in 1895, plum trees were also considerably injured by the insect in some parts of Colorado. The redbud tree, dwarf oaks, alder, rye and sugar beets are also to be included in the menu of the grape leaf-hopper. It is doubtful, however, whether it breeds freely on more than the wild and cultivated grapes and the Virginia creeper.* Practically all of the "hoppers" in the recent Chautauqua outbreak were of the typical *comes* variety, which is shown at *a* and *b* in Fig. 16.

VII. THE LIFE-HISTORY OF THE INSECT

As no one had read from Nature's book the complete life-story of this grape leaf-hopper during its yearly life-cycle, we devoted much time in the field and insectary in learning the story. Harris briefly outlined the story more than sixty years ago and it is only within a few years that one or two chapters have been added or filled in. The results of our observations for two years in New York vineyards are graphically portrayed in the "life-cycle" picture in Fig. 15. Note that there are but three life-stages of this insect—eggs, nymphs and adults—the young insects gradually developing wings through five nymphal stages.

Hibernation.—In all parts of the country the grape leaf-hopper passes the winter in the adult or winged stage. In California, it is said that only the youngest adults survive the winter, the late nymphs and older adults being destroyed by the wholesale in early winter every year. While the winter weather conditions are doubtless one of the most potent of Nature's methods of checking this insect, we have no definite evidence as to how much their numbers were lessened in winter in Chautauqua county during the past few years. Judging from the swarms of them which appeared in the spring on the vines, a large majority of those that went into hibernation in the fall must have survived the winter.

As soon as the leaves begin to die and drop from the vines during September and October, the active adult "hoppers" migrate from the vines and seek winter quarters. In the autumn of 1901, people driving or bicycling for pleasure in Westfield were much annoyed by the swarms of migrating "hoppers" that filled the air. Comparatively few of them find suitable hibernating places near the vines in the vineyards unless neglect has allowed a carpet of weeds and grasses to grow. A neighboring tract of woodland, or a little valley, ditch or swale overgrown with brush, or a bordering strip of thick grass, or a pile of grape leaves blown together in autumn, or a mulched strawberry bed forms an ideal place, and in all such places the "hoppers" have passed the winters in Chautauqua county. It was often very noticeable that those parts of vineyards nearest such suitable hibernating places suffered the most from the "hoppers." May 2nd, 1902, we found several hundred of them in a clump of grass less than one foot square in one vineyard. On sunshiny days during warm spells in winter, the "hoppers" emerge from their snug retreats in the grass or beneath fallen leaves and fly about more or less.

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* The following species of leaf-hoppers of the subfamily *Typhlocybinae* have been found on grape-vines : *Dicraneura cockerellii*, *Empoasca unicolor* and *mali*, *Typhlocyba tricincta*, *trifasciata*, *obliqua*, *illinoiensis*, *comes* and its nine varieties, *vulnerata*, *tenerrima* and *rosæ*. However, only the single species *comes* has ever occurred in injurious numbers on grapes.

Another larger leaf-hopper, known as *Tettigonia circillata* and belonging to a different subfamily, is injurious in the Santa Clara Valley in California, where it replaces *Typhlocyba comes* which is a serious pest in other parts of the state.

Emergence and feeding habits in spring.—About May 1st—a little earlier if it is warm—the hibernated adults emerge and begin feeding on most any succulent growth that is available, such as young beeches and maples in the woods, and the grasses, strawberries, dewberries, or raspberries near vineyards. Sometimes the foliage of these berries are noticeably injured by the "hoppers" at this time.

After a few days of this spring foraging, the conspicuous reddish markings on the wings and body gradually change to a light lemon-yellow color. So different were these yellow-marked forms, that some thought a new brood had been developed on the spring food-plants, but there was no other evidence of this.

By May 15th, in the Chautauqua grape belt, the grape foliage was out sufficiently to attract the leaf-hoppers which then swarmed into the vineyards by the millions. The lower leaves were first attacked, and as the season advanced and more foliage appeared, the "hoppers" worked upward on the vines. They live almost entirely on the under sides of the leaves, sucking their food therefrom by means of their sharp beak. These adult "hoppers" are very active creatures, leaping and flying quickly when a leaf or vine is disturbed. They run readily in any direction and are aptly called "hoppers." On a bright, warm day swarms of them would rise from a vine the moment our spray struck it, but on cool, dark days they are much less active. These hibernated, adult leaf-hoppers continue to work on the grape leaves in gradually lessening numbers until August, or until many of their children develop through their nymphal stages and become adult "hoppers."

The egg-stage.—Harris guessed that the eggs of this grape leaf-hopper were "laid upon the leaves" in the spring, and more than half a century passed before any more definite information was recorded.* The eggs were

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*In 1891, Townsend (Bull. No. 3, N. Mex. Expt. Sta.) stated that the eggs were inserted singly in punctures made in the leaves and stems of the vine, usually on the underside. The presence of these punctures may be known, he said, by a very small, globular exudation of sap. He observed these exudations as early as April 30th, in great numbers.

We saw many of these exudations on the leaves in Chautauqua county in 1902, but we never found an egg there nor did we ever find the exudation where an egg was laid. It is thus doubtful if Townsend saw the place of oviposition, the exudation probably being natural to the plant.

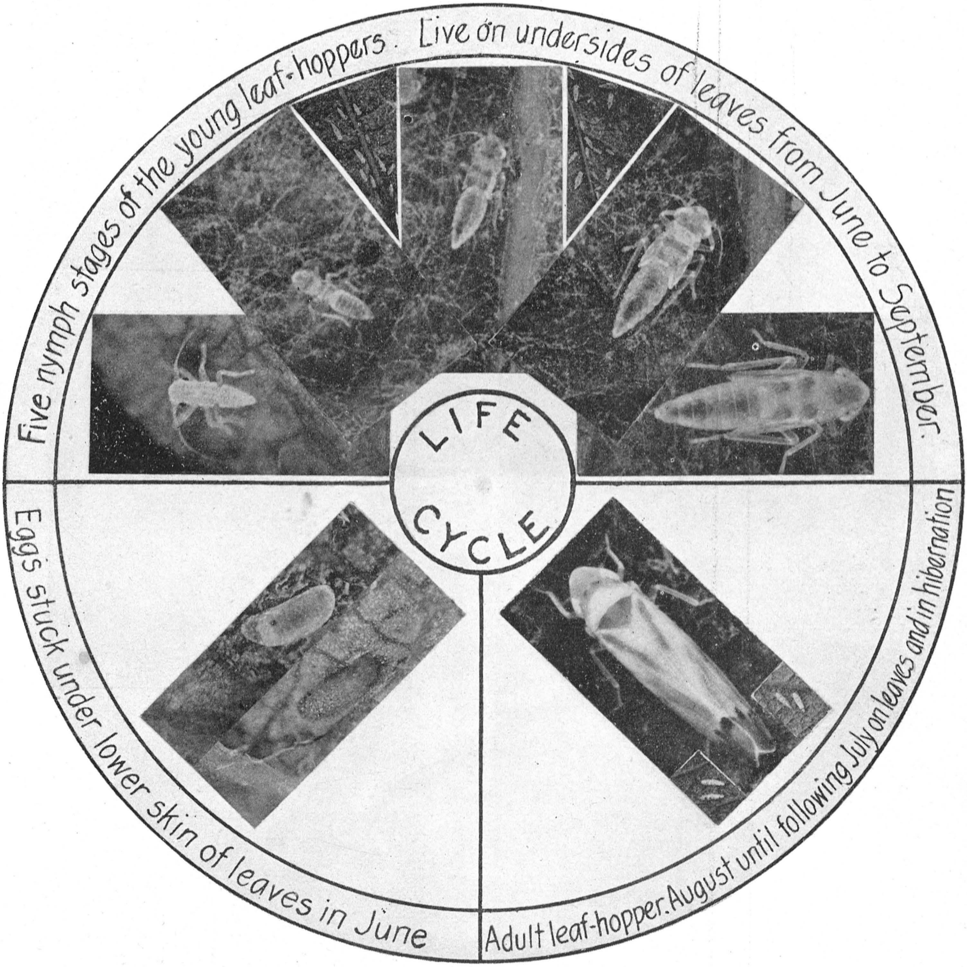
Five nymph stages of the young leaf-hoppers. Live on undersides of leaves from June to September.
LIFE CYCLE
Eggs stuck under lower skin of leaves in June
Adult leaf-hopper. August until following July on leaves and in hibernation

FIG. 15.— *The life-cycle of the grape leaf-hopper.*

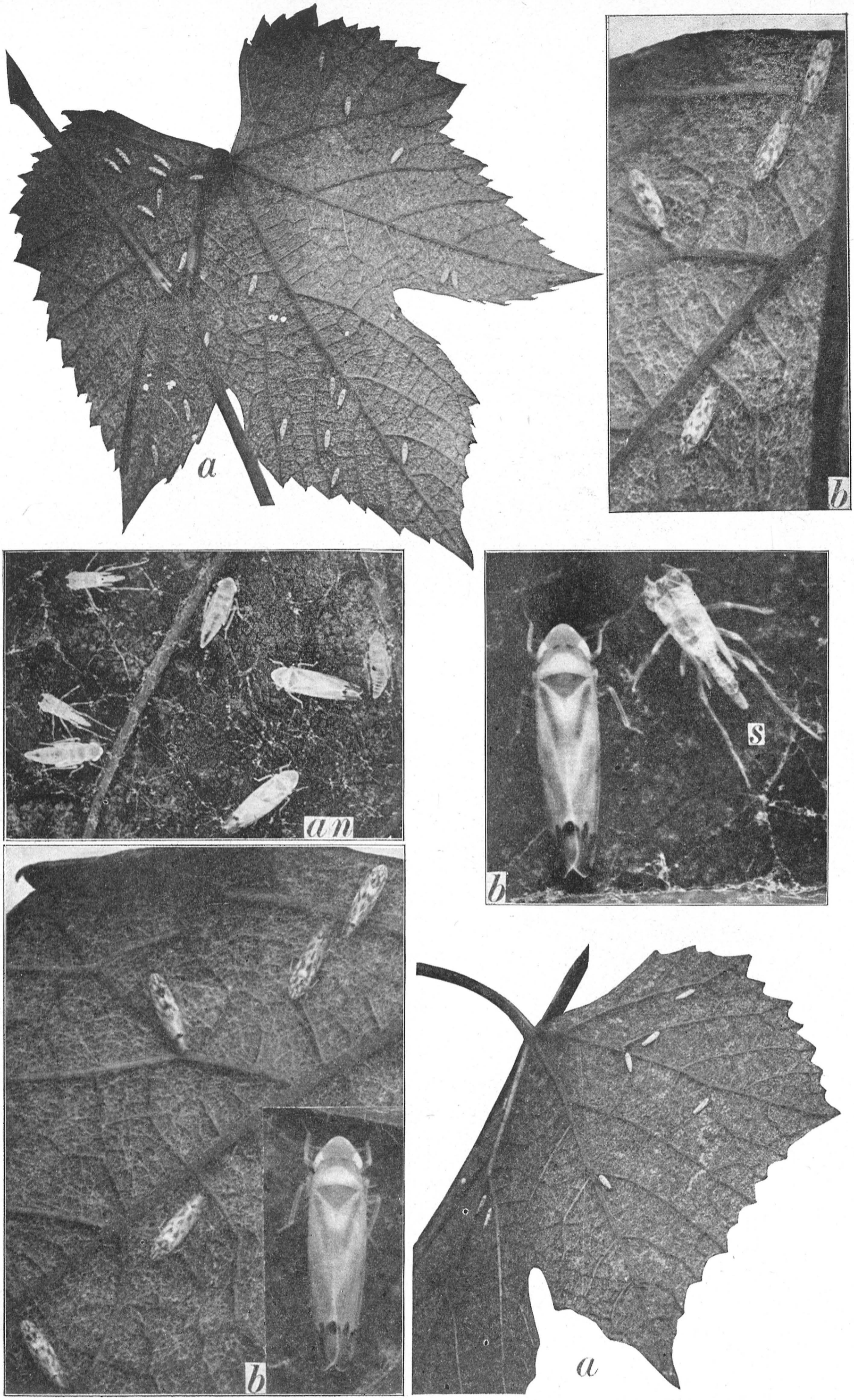

FIG. 17.—*Adult grape leaf-hoppers. Natural size on leaves at a, a; enlarged at b, b, b; a n, shows adults and nymphs; and at s, is the old nymph skin just shed by the adult nearby. All from life.*

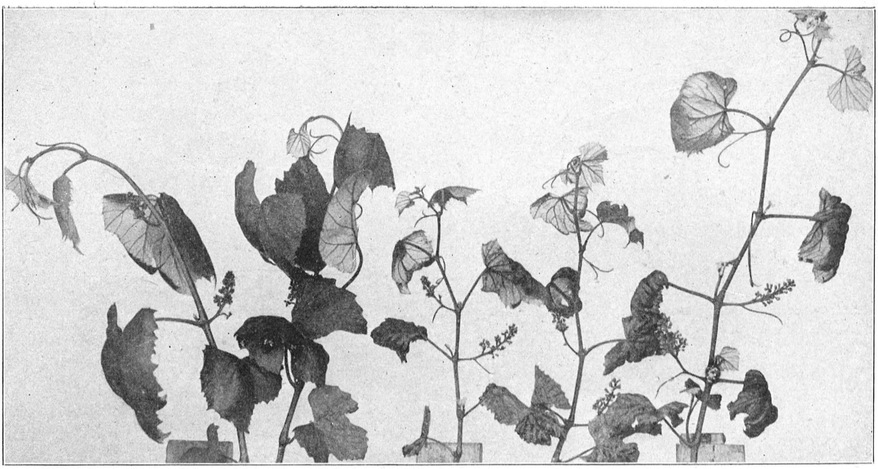

FIG. 19.—*The three branches on the right were badly injured by the adult leaf-hoppers in the spring. Compare with the two branches from an uninfested vineyard.*

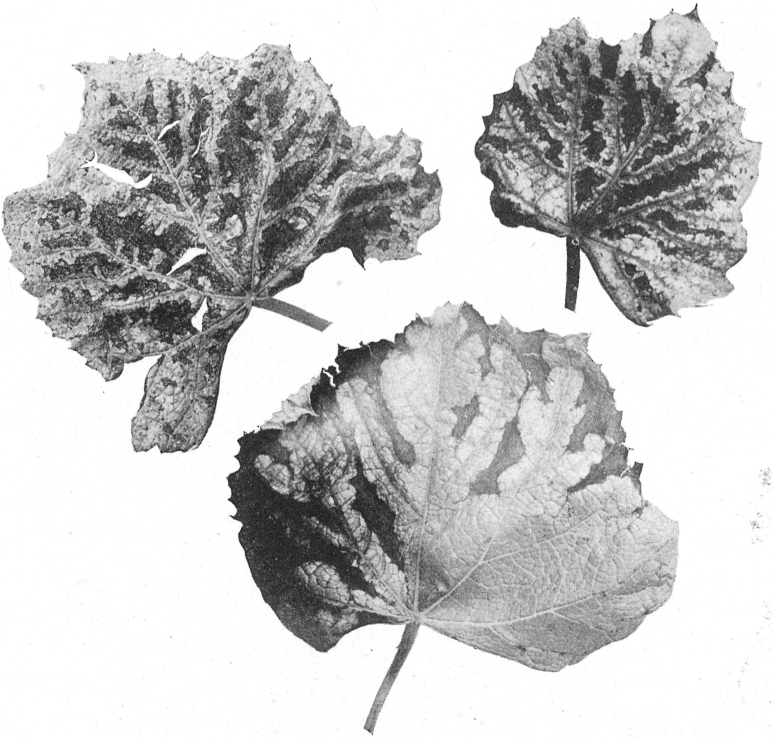

FIG. 20.—*The two upper leaves show the destructive work of the adult leaf-hoppers in the spring. The lower leaf was injured by an oil and water spray.*

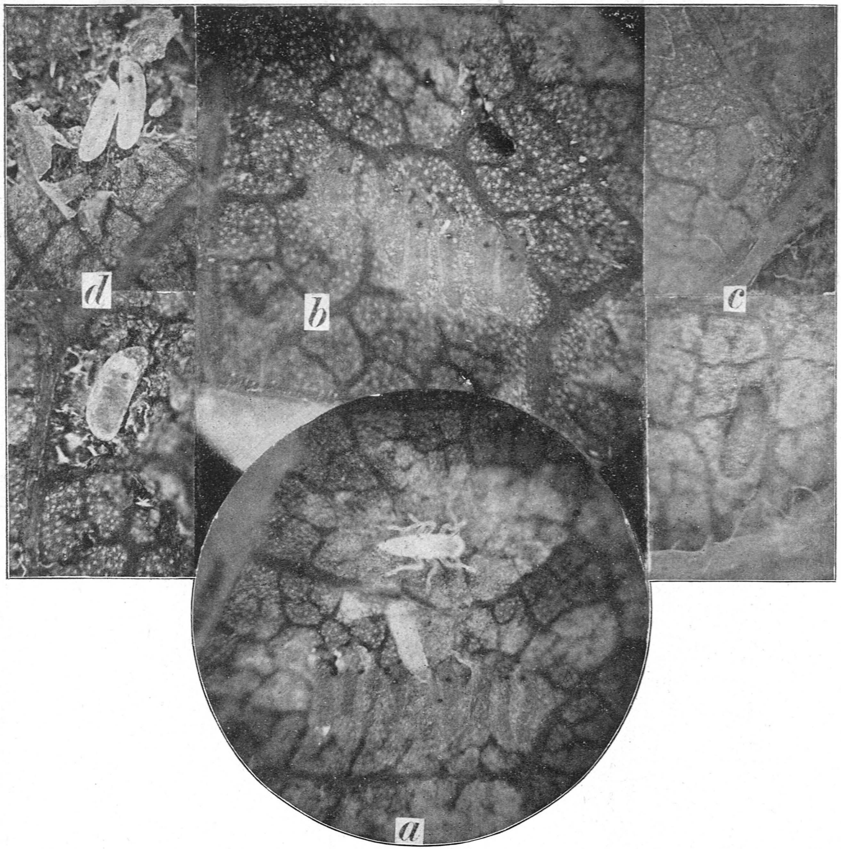

FIG. 21.—*Eggs of the grape leaf-hopper ; a, nine eggs in a row, the middle one just hatching, with baby nymph above ; b, six eggs in a row with eyes of nymphs showing distinctly ; c, eggs laid singly ; d, eggs exposed by removing skin of leaf. All much enlarged. First time the egg has ever been pictured.*

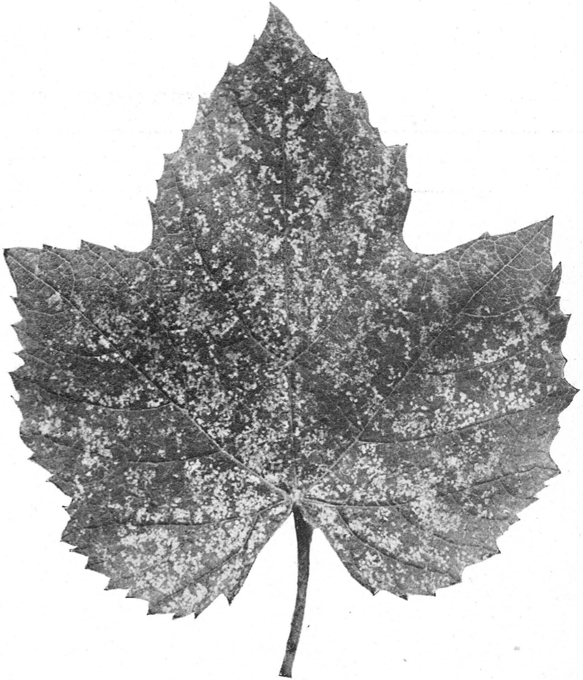

FIG. 23.—*Grape leaf showing the work of the nymphs of the grape leaf-hopper.*

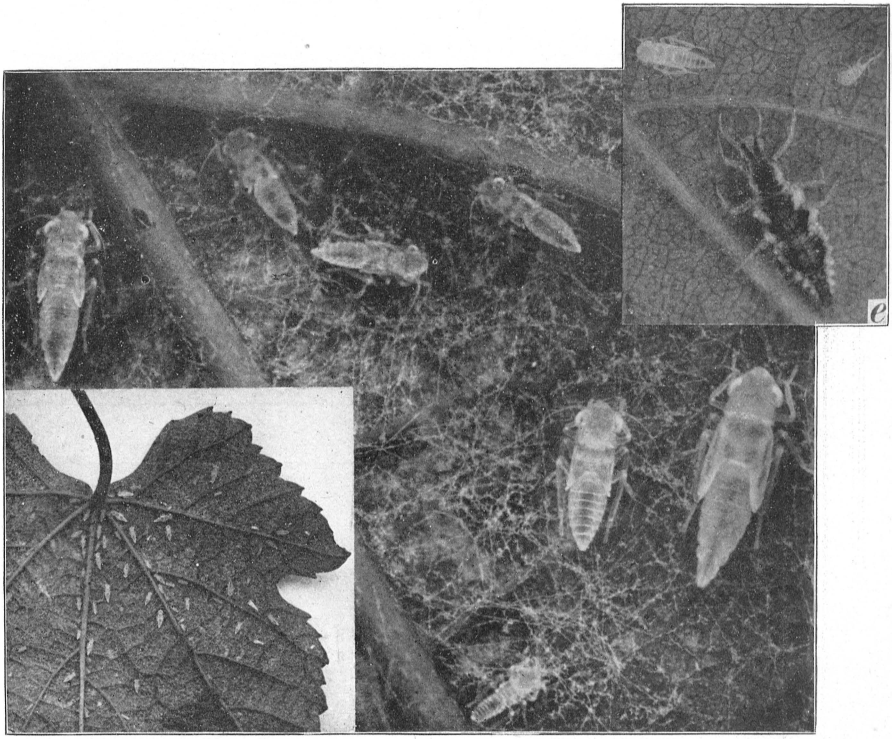

FIG. 24.—*Nymphs or young grape leaf-hoppers; natural size on leaf at left. At e, an aphis-lion is including nymphs in its menu* (*enlarged*).

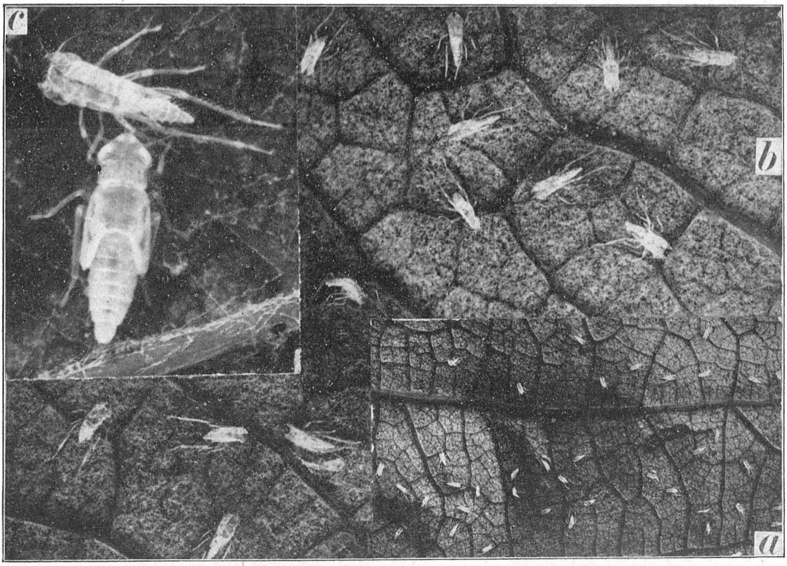

FIG. 25.—*Cast skins or "old clothes" of nymphs attached to leaves. Natural size at a, enlarged at b, and a nymph and his last "old suit" at c much enlarged.*

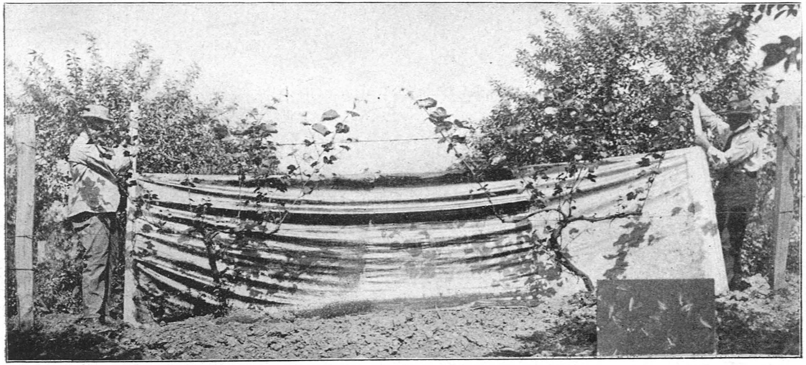

FIG. 26.—*Tarred strip for catching the adults. Too cumbersome.*

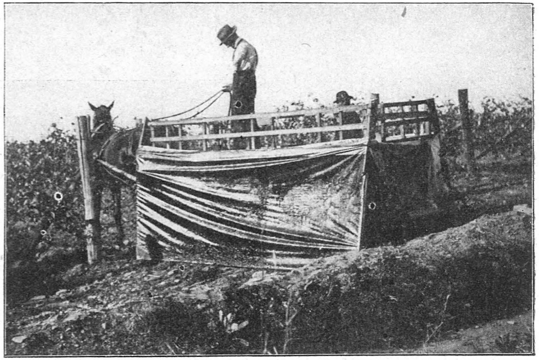

FIG. 27.—*Sticky strips on each side of a grape truck. Not satisfactory.*

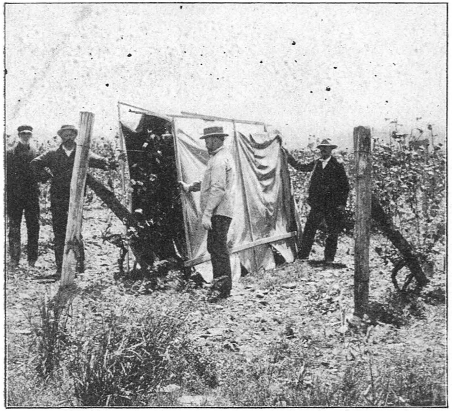

FIG. 28.—*A sticky canopy "catcher." Too unwieldy.*

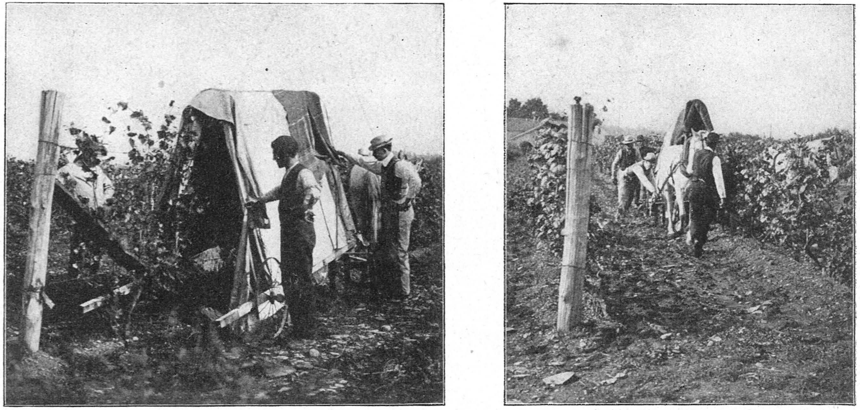

FIG. 29.—*A sticky canopy "catcher" drawn by horses over the trellis. Soon discarded as impracticable.*

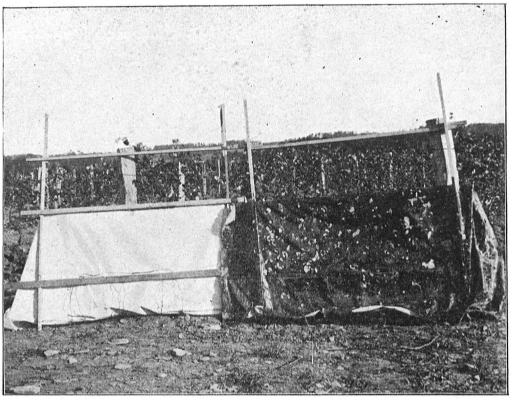

FIG. 30.—*A practicable sticky shield for catching the adult leaf-hoppers in the spring.*

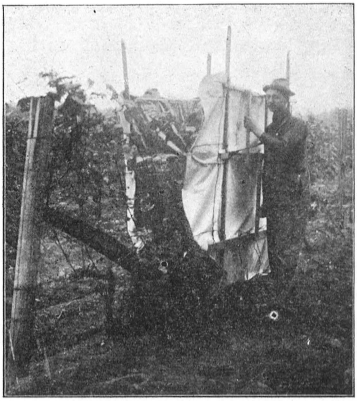

FIG. 31.—*Higher sticky shields had to be used later in the season.*

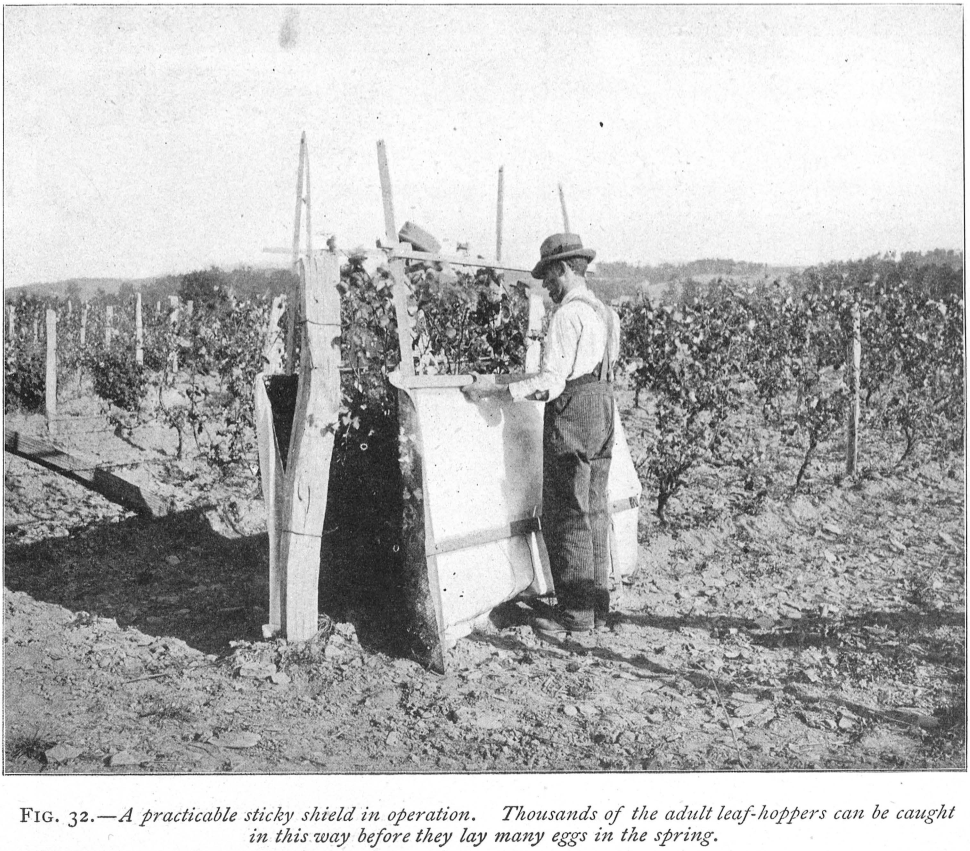

FIG. 32.—*A practicable sticky shield in operation. Thousands of the adult leaf-hoppers can be caught in this way before they lay many eggs in the spring.*

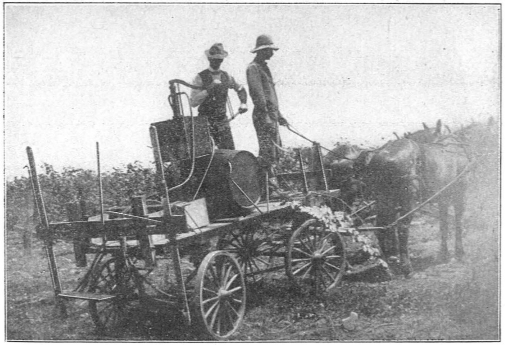

FIG. 33. *Arrangement of fixed nozzles for spraying adult leaf-hoppers.*

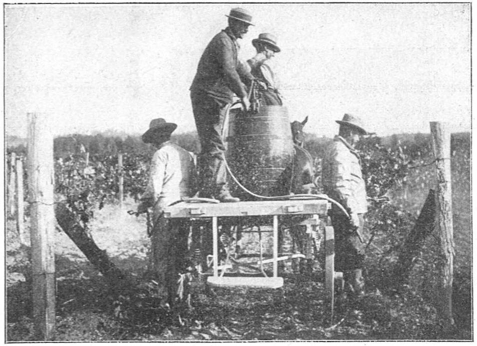

FIG. 34.—*Killing the adult leaf-hoppers, with an oil and water spray.*

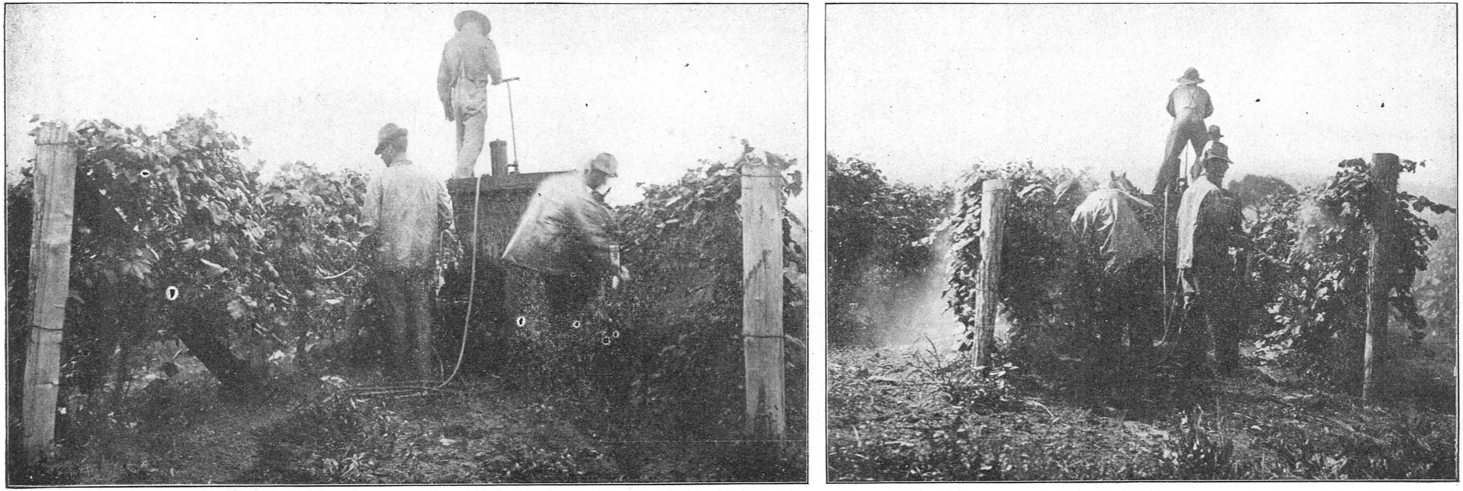

FIG. 35.—*Killing the nymphs with a whale oil soap spray in July.*

probably first seen in 1899 in California and a year or two later in Colorado.* It was not until the hibernated "hoppers" had been feeding for more than a month that we saw any of them pairing. The location of the eggs was first discovered in the East by Mr. Fred Johnson, one of our enthusiastic assistants at Westfield, on July 19th, 1902 ; he saw a nymph just hatching and eggs were soon found. So obscurely are they tucked away just beneath the lower skin of the leaves, that one no longer wonders they remained unseen for so many years. Usually they are laid singly in various locations on the undersides of the leaves as shown at *c* in Fig. 21. On Concord leaves they are to be found with much difficulty, but on the thinner, smoother Clintons in Canada we found them readily, sometimes laid from six to nine in a row, as shown at *a* and *b* in Fig. 21 ; the dark spots showing in the eggs are the red eyes of the developing young "hoppers." At *d* in this figure, we have torn away the skin of the leaf thus laying bare the delicate or easily crushed, semi-transparent, slightly curved eggs of a faint yellowish tinge and only three-fourths of a millimeter (.03 inch) in length. The female is provided with a slender and sharp ovipositor, shown in Fig. 22, well adapted for inserting the eggs under the skin of the leaf.

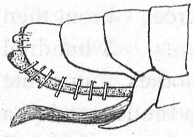

FIG. 22.—*Caudal end of adult grape leaf-hopper showing the ovipositor much enlarged.*

The duration of the egg-stage being unknown, we arranged experimental cages and our observations indicate that the eggs hatch in from 9 to 14 days in June. Apparently egg-laying did not begin in Chautauqua vineyards until about the first week in June, or after the hibernated "hoppers" had been feeding for nearly a month, half of this time on the grape-vines. How many eggs one grape leaf-hopper may lay, we did not determine. The eggs are about one-third as large as the insect, but as egg-laying probably continues for two months or more, doubtless a comparatively and surprisingly large number of eggs are gradually developed and laid by a single female during the summer.

The nymphs or young "hoppers."—We celebrated the fourth of July, 1902, by watching several young "hoppers" hatch from the egg. It is a tedious process. They gradually work themselves out of one end of the egg ; just below the baby "hopper" at *a* in Fig. 21, is shown a nymph nearly out of the middle one of the nine eggs laid in a row. A nymph was 10 minutes getting out of the egg, and another 10 minutes were required to get its legs and antennæ in condition so it could walk and begin its life work, as shown at *a* in Fig. 21. The nymphs which are of a whitish color with red eyes when born, grow slowly, gradually acquiring yellowish stripes along their sides and developing wings in little wing-pads or pockets, as is graphically shown in the "life-cycle" picture in Fig. 15 and also in Fig. 24. As growth continues they shed or molt their old skins and appear in a new and larger suit. We have watched several of these nymphs in our cages from the time they were born through five distinct stages, each marked by a molting of the skin, until finally they reached the adult stage. About five days were spent in each of the first three nymph stages, six days in the fourth stage and twelve days in the fifth stage. Thus from 30 to 33 days in summer are required to develop the grape leaf-hopper through its five nymphal stages in New York.*

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* Clarke in An. Rept. Calif. Expt. Sta. for 1897–98, dated 1900, p. 179; Gillette in An. Rept. Colo. Expt. Sta. for 1900, dated 1901, p. 3.

The nymphs or young "hoppers" begin to appear on the grape leaves in New York about June 15th and by July 1st are out in full force. From then until October, nymphs in all stages may be found on the leaves. A hundred or more nymphs often infest a single leaf. Their "old clothes" or white skins are left where shed, and they often remain attached to the leaves for a long time, looking very life-like, as shown in Fig. 25; the part of leaf at *a* (natural size) shows how thickly these various sized shed skins may be strewn about; at *b* some are enlarged, and at *c* is shown a nymph (much enlarged) beside its recently-shed fourth suit or skin.

Work and habits of the young "hoppers."—The nymphs live on the undersides of the grape leaves and suck their food like their parents or adult "hoppers." They first appear on the lower, older foliage where their parents worked, and later they infest nearly every leaf. These nymphs are active little creatures, scurrying away in all directions when disturbed. They often run onto the uppersides of the leaves or along the leaf stalks as if to hide.

In 1841 Harris stated that if the young "hoppers" are disturbed, "they leap from one leaf to another with great agility." As practically all writers, even to the present time, have made similar statements about the nymphs, we were much surprised to find that *they would not leap or jump* in any nymphal stage in spite of all traditions and all our efforts to make them do so. They are good runners in most any direction, but they would not leap a millimeter for us.*

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* *Notes on the five nymphal stages.—First stage.*— Nymphs are of a general semi-transparent whitish color, including legs and antennæ; after feeding begins, the abdomen becomes slightly yellowish; the eyes are conspicuously dark red; duration of stage, 5 days. *Second stage.*—General color the same, with thorax yellowish and a distinct yellow stripe appearing along each side of the thorax at bases of the wing-pads which just begin to show; eyes are less conspicuous with an irridescent whitish appearance; duration of stage, 5 days. *Third stage.*—Abdomen becomes slightly brownish from food, and legs have yellowish tinge; yellowish stripes on sides now extend onto head; the wing-pads now extend nearly to caudal border of first abdominal segment; duration of stage, 5 days. *Fourth stage.*—General color the same; lemon yellow side stripes now extend along the cephalic borders of the segments and meet on the median line of first thoracic segment; eyes of a bluish-white irridescent color; the wing-pads extend back to caudal border of second abdominal segment; duration of stage, 6 days. *Fifth and last nymphal stage.*—The wing-pads now reach just beyond the caudal border of the third abdominal segment, and the front pads have a lemon yellow stripe on them; some specimens have yellow hind tibiæ, and yellow spots occur on each segment of the abdomen along the sides of dorsum; duration of stage, 12 days.

The effect of the work of the nymphs on the leaves is well shown in Fig. 23. The upper surface of the green leaf presents a mottled, yellowish appearance. Even on badly infested vines, we have never seen the leaves so seriously injured by the nymphs in summer as by the adult "hoppers" either in the spring or late summer and autumn. Rarely does a leaf turn brown and die from the work of the nymphs, but the foliage is weakened so much that it falls an easy prey to the adult "hoppers" into which the nymphs soon develop.

Number of generations of the insect.—In 1898, Marlatt recorded that "in the middle and southern portion of its range, the grape leaf-hopper undoubtedly passes through 4 or 5 broods annually, the life of a single generation probably covering about a month." In 1879, Riley had also guessed there were several generations in a season. After watching the insect in the field and insectary from May till November, we were surprised that our observations followed quiet closely Harris's apparently forgotten sketch of its life more than 60 years ago. He outlined but one generation of the insect in a year ; the nymphs first appearing in June, developing into adults in August, and these hibernating.

For the past two years in Chautauqua county, the hibernated adult "hoppers" began work on the grape-vines about May 15th, the nymphs first appeared about June 15th, and some of these had developed into adults by July 15th. The life-cycle from egg to adult is from 6 to 7 weeks in New York ; about 2 weeks are spent in the egg and nearly 5 weeks are required to get through the five nymphal stages. We expected to see another brood of nymphs, and in August a few adults were seen pairing. As late as September 12th, we also found newly-hatched nymphs, but our observations for two years indicate that only a very small second brood of nymphs appear in the autumn in New York. Nearly all of the adult "hoppers" appearing in August and later go into hibernation and do not lay eggs until next June Thus there is but one full generation and a partial second brood of the nymphs of the grape leaf-hopper in New York in a year. It is doubtful whether any of the nymphs of the second brood develop into adults before killing frosts. In more southern localities, doubtless two or possibly more generations occur. Townsend recorded two generations in New Mexico in 1892, and Gillette reports the same for Colorado.†

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* Gustav Eisen seems to have been the first to contradict this common notion in his book on the *Raisin Industry* in 1890 (p. 98). We regret to be obliged to discard the stereotyped tradition of more than 60 years that the nymphs leap, but it is not the first time that such has been done; how the eggs of the codling-moth stuck in the blossom end of the apple in our literature !

† Townsend in Bull. No. 5, N. Mex. Expt. Sta., p. 3, 1892.

In September, 1902, Professor Gillette of Colorado wrote us that there "the variety *coloradensis* grows in two broods. The second brood is hardly matured when frost destroys the leaves of the grapes." Also recorded in Ann. Rept. Colo. State Bd. of Hort. for 1902, p. 74 (1903).

Notes on the adults in autumn.—From August until the grape leaves fall, the adult "hoppers" swarm over the vines, sucking the life from the leaves. The devastated parts of vineyards are conspicuous from a distance as brown blots on the landscape during late summer and autumn. We have counted nearly 100 adults on a single grape leaf. Evidently many of them migrate to other vineyards where the pasturage is better in the fall. They rise from the leaves in swarms when one simply walks near a vine. In leaping and flying from one leaf to another in autumn, the noise reminds one of a light shower of rain, and in fact we were thus misled for a moment several times in the vineyards in September, 1902.

As early as August 14th in 1902, we observed that the yellow summer markings on many of the adults were gradually becoming reddish, beginning near the thorax. This meant that they were preparing for winter. We noted in October that these reddish-marked " hoppers " were much less conspicuous on the old, browned and dying leaves than they would have been with the yellow coloration. Thus this color-change is doubtless of much use to the insect in giving it a protective resemblance to its surroundings when in hibernation. This probable adaptional change in color does not seem to have been noticed before.

After October 1st the adult leaf-hoppers usually begin to seek their winter quarters. They remain in hibernation till April or May, and some of them live on until August or for nearly a year, and long enough to see their baby " hoppers " develop into adults.

Summary of the life of the grape leaf-hopper.—The adult grape leaf-hoppers (Fig. 17) hibernate largely in nearby grass and wood-lands, and emerge about May 1st to feed for two weeks or so on various plants where their reddish winter coloring changes to a lemon yellow, and then they go to the grape foliage, spending the rest of the season thereon. About June 1st egg-laying (Fig. 21) begins and continues for several weeks, the eggs hatching in about two weeks. The young " hoppers " or nymphs (Fig. 24) live on the undersides of the leaves through five different nymph stages, their " old clothes " or cast skins (Fig. 25) often remaining on the leaves for weeks. The nymphs run rapidly but, contrary to tradition, they do not leap or hop. After about five weeks of this nymphal life, they appear as flying and leaping adults in August. Evidently some of the first of these adults to appear lay eggs which develop a partial second brood of nymphs in New York, but most of them soon take on their protective, reddish, winter coloration and in October go into hibernation. Some of these hibernating adults doubtless live from one August until the next, or for nearly a year. There is but one full generation and a fragment of a brood of the insect in New York vineyards in a year. The yearly life-cycle is graphically portrayed in Fig. 15.

VIII. NATURAL CHECKS AND ENEMIES

Doubtless certain weather conditions are the most efficient of Nature's checks against the grape leaf-hopper. It has been a common notion for forty years that the "hoppers" are most numerous in dry seasons. It is probable that preceding dry years helped the more potent factor of neglected vineyards in bringing about such a disastrous infestation as occurred during the past three years in Chautauqua county. But the season of 1902 was excessively wet, drenching storms fell frequently, and yet but few even of the smallest nymphs on the leaves were washed off or in the least discouraged in their nefarious work. Apparently as many old "hoppers" went into hibernation in 1902 as the preceding year, but it became evident early in 1903 that not so many were at work. Whether the winter conditions were not so favorable or the extreme drouth in the spring caused this, we do not know. In 1865, Trimble observed that once when the thermometer reached 100°, thousands of the "hoppers" were killed.

Natural enemies.—The grape leaf-hopper has but few natural enemies. In 1862, Walsh saw one of the Dance-flies (*Hemerodromia superstitiosa* Say) feeding on the "hoppers" in Illinois. The Glassy-winged Soldier-bug (*Hyaloides vitripennis*) has been accused of eating them by Glover (1875) and others. Perkins records an unidentified predaceous enemy in Vermont in 1878. A Pennsylvania correspondent of Dr. Lintner in 1891, stated that his attention was attracted to the insects by the "sparrows in their efforts to gobble them."

In June, 1902, we saw red mites eating young "hoppers;" Mr. N. Banks had given these little mites the manuscript name of *Rhyncholophus parvulus*. Some of the nymphs were also devoured by the rapacious aphis-lions, as shown at *e* in Fig. 24. None of these predaceous enemies, however, have ever noticeably reduced the numbers of this grape pest.

Thaxter states that in 1890, grape leaf-hoppers were doing injury in a Connecticut vineyard in September. They were then attacked by a species of *Empusa* fungus which eventually destroyed them entirely. He transferred the disease to cabbage worms which also died from it. We have seen no indications of a fungous enemy of this pest in New York, and evidently its enemies will help the vineyardist but little in controlling it. But its life-pendulum is much affected by weather conditions and these are doubtless largely responsible for the evident beginning of another "down" or non-destructive period in the insect's history.

IX. EXPERIMENTAL WORK AGAINST THE GRAPE LEAF-HOPPER

BY M. V. SLINGERLAND AND JOHN CRAIG

During the summer of 1902, the authors and two Cornell Agricultural students, Messrs. Bell and Hosford, spent much of their time in the infested region in Chautauqua county devising and testing methods for combating this grape leaf-hopper. It was a strenuous warfare, often extending from daylight till dark and sometimes far into the night. The students took an active part in whatever was done, no matter how disagreeable the task or how long the hours. We coöperated with the vineyardists; they had not found it necessary to fight insect foes and few were prepared to do it or knew how.

Several vineyards were freely placed at our disposal for experiments and the fight began early in June when the old hibernated "hoppers" were working on the lower leaves of the vines.

Experiments with sticky shields.—Professor Lazenby* of Ohio, seems to have been the first to suggest the use of sticky shields to catch the adult "hoppers" when they jumped and flew from a disturbed vine. A long strip of building paper was painted with tar on one side and carried alongside a row of vines (Fig. 26) while some one on the other side drove the "hoppers" onto it by jarring or otherwise disturbing the vines. The recent recommendations from New Jersey and California have reduced this sticky shield to a shingle or fan, and it is reported that 90 per cent of the old "hoppers" can be caught in a net in California. It hardly seems possible that, even with cheap labor, it would be practicable to treat extensive vineyards with an insect net or a sticky fan. Even in Chautauqua vineyards of from 10 to 100 acres, such small devices seemed inadequate and the vineyardists demanded more wholesale methods.

We therefore began with a Lazenby, sticky, table-oilcloth shield about 14 feet long, smearing it with coal tar and other materials, and pine tar, as shown in Fig. 26. The pine tar was the most effective substance that we tried on this device. But this shield proved too cumbersome. A similar shield was then built on each side of a grape truck, as shown in Fig. 27, to be driven between the rows and get the "hoppers" from two rows of vines at the same time. Owing to considerable irregularity in the distances between the different rows of vines and to more or less rough ground, this device did not work satisfactorily. One ingenious grape-grower arranged a smooth, non-sticky oilcloth on a frame attached to one side of a wagon in such a way that it could be tilted at different angles and a tin trough containing kerosene was fixed at the bottom to catch and kill the "hoppers" as they slid into it; many were caught with this device, but more did not get into the oil. We next built a canopy of oilcloth over a light frame, making the inside sticky, and carrying it over a trellis of vines, as shown in Fig. 28. As no "hoppers" were caught above four feet from the ground and the whole device was too unwieldy and expensive in labor, it was discarded. An interested vineyardist devised a similar canopy to be drawn by horses over the trellis, as shown in Fig. 29. But this device was also soon consigned to our rubbish heap of impracticable devices.

We had learned much, however, which finally resulted in the practicable and efficient shields shown in Figs. 30 and 32. Make a light wooden frame about seven or eight feet long and four feet wide, having the bottom cross-piece about a foot from the ground and fasten to this stiff wires extending down nearly to the ground and bent inward something like hay-rake teeth. Tack over this a strip of table-oilcloth one and one-fourth yards wide and let it extend down over the curved wire teeth, so that when the shield is held beside a vine the oilcloth will come under the vine to catch the "hoppers" that try to drop to the ground. Cover the oilcloth with the "stick-em" and all is ready to operate The extension of the side-pieces above the cloth as shown in the figures is unnecessary; they were part of our discarded canopy "catcher." Two men, each carrying one of these light, sticky shields on opposite sides of a trellis of vines, as shown in Fig. 32, can reach over the shields, jar the vines to disturb the "hoppers," and thus go over an acre of vineyard in little more than an hour.

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* This is usually credited to Lintner who strongly recommended it in 1887 and later, but Lazenby suggested it in 1882 in the Report of the Ohio Horticultural Society.

Late in May or in early June is the best time to use these sticky shields, for then the "hoppers" are on the lower leaves and have not yet laid their eggs. Later as the vines grew, we had to use higher shields, as shown in Fig. 31, and these could not be operated so easily and rapidly.

Several vineyardists who had watched the experiments with much interest were convinced that in these simple sticky shields we had at last something practicable, cheap and rapid in operation, and that many of the old "hoppers" can thus be caught in the spring.

The best sticky substance we found to be a mixture of melted resin, one quart in one pint of castor oil, making practically a sticky fly-paper; the much cheaper "castorine" can doubtless be used in place of the castor oil. The O. & W. Thum Co., Grand Rapids, Mich., manufacturers of "Tanglefoot" fly-paper, have furnished us a suitable preparation for sticky shields at about 15 cents a pint. The "hoppers" are exceedingly "light-footed" and it requires a very sticky substance to make the required flying catch.

Spraying and dusting the adult "hoppers."—In the first horticultural account of this pest in 1828, the "alkalies and tobacco-juice" were pronounced only partially effective, and a tobacco fumigation tent on wheels to go over the trellis was described and recommended as effective.* Whale oil soap was recommended as early as 1865, and during the next fifteen years, dozens of different sprays and dusts were suggested. Among the sprays were carbolic acid mixtures and kerosene emulsion, and the dusts included lime, sulphur, hellebore, cayenne pepper, wood ashes and pyrethrum. Many failures are recorded with these substances when used against the adult "hoppers." For example, in 1879 in Michigan one vineyardist sprayed his vines with carbolic acid, benzine and kerosene mixed separately in water, and with tobacco tea; then he dusted on lime and sulphur, and he burned tar and tobacco stems and put vinegar on chloride of lime under the vines, hung sprigs of tansy, cedar, tomato and strawberry among the vines, and burned torches of pine dipped in kerosene; and all of these measures "disturbed them somewhat but failed to diminish their numbers or ravages." In 1896, Pettit made some careful experiments in Minnesota against the adults with kerosene-water mixtures, tobacco soap, whale oil soap, and "Scabcura" sheep-dip; only the kerosene and water mixture containing 10 per cent of kerosene was at all effective.

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* Although Harris recommended only this fumigation method for combating the pest, it was soon discarded as impracticable in vineyards.

We began the spraying experiments against the adult "hoppers" early in June, 1902. A local enthusiast insisted that a special dose of his (which proved to be saltpetre) would kill them, and although we used it eight times as strong as recommended, not a "hopper" was hurt by it. Bonanza lye, 1 lb. to 5 gals., killed few if any and injured the foliage. A combination of this lye, whale oil soap, tobacco water, and a little tar gave no better results. Crude petroleum, from 15 to 40 per cent in a mechanical mixture was not nearly so satisfactory as kerosene oil. Whale oil soap, 1 lb. to 5 gals., killed a few and hurt the youngest leaves. Tobacco water (1 lb. in 1 gal. of hot water for one hour) killed none, and a mixture of this with whale oil soap was no better. Two local "dopes" of carbon bisulfide and lime and sulfur had no effect on the "hoppers." The standard Bord eaux mixture killed none nor gave any protection to the leaves. A mixture of equal parts of air-slaked lime and sulfur dusted on the vines had no effect.

Kerosene oil proved to be the most effective application for the adults that we tested. A standard kerosene emulsion diluted to 13½ per cent of kerosene killed but few "hoppers." But a mechanical mixture of kerosene and water containing from 15 to 20 per cent of oil, killed them when thoroughly hit with it; the grape foliage, however, was injured with only 10 per cent of oil. Finally we succeeded in killing many of the old "hoppers" by setting the pumps to throw 5 per cent of kerosene and with this going over 50 or 75 vines or one row and wetting the "hoppers" and knocking them to the ground (Fig. 34). While they busied themselves there trying to wipe it off with their legs, we changed the pumps to throw 25 per cent of oil and then came back the same row of vines and killed thousands of them on the ground. Several acres of vineyard were treated in this way, but in a few days considerable injury to the foliage developed. The leaves turned brown in spots, as shown by the lower leaf in Fig. 20. Tests were at once made of several kinds of these oil and water pumps; and they were found to vary considerably from 5 per cent, certainly enough to explain the injurious effect on the foliage. When the pumps can be relied on to throw very nearly the percentage of oil scheduled, this method of knocking off the "hoppers" with a 5 per cent spray and then "hitting them when they are down" with 52 per cent of oil the cheapest and most practicable method that we tested for killing the adults in the spring. Recent experiments in other States confirm our experience and show that pumps are often unreliable, sometimes giving (according to Georgia experiments) during continuous pumping from 10 to 82 per cent of oil when set at 15 per cent.

Much time was spent in trying to arrange a series of fixed nozzles so that one could drive between two rows of vines and spray one side of each row, (Fig. 33), but not nearly so effective work was done as when two men walked behind and directed the nozzles at the insects, which must be hit with the spray (Fig. 34). It is doubtful whether the horse-power spray pumps or any arrangement of fixed nozzles can be used against this pest with half the effectiveness of stationary pumps with hand-directed sprays, largely because there must be time to direct the spray so it will hit the insects.

We believe it is feasible to mount an ordinary barrel spray pump and one of the oil and water pumps on a grape truck, with 25 or 30 feet of hose on the latter pump so one could follow behind the nozzle from the first pump. Use a whale oil soap spray of 1 lb. soap in 6 or 7 gals. of water in the first pump to knock the "hoppers" to the ground, where the second man can soak them with an approximate 25 per cent spray of kerosene from the other pump. It is a critical period when these old "hoppers" are swarming on the vines in the spring before they have laid their eggs, and good work done then will show throughout the season. If 50 to 75 per cent of the adults could be killed in the spring, the insect would be reduced beyond the danger limit for the season.

We tried knocking the old "hoppers" to the ground with water, but they would not remain down long enough and many were not brought down at all. We did not find any one kind of a spray or dust which was practicable to use with safety on the grape foliage that would kill a majority of the adult "hoppers" in the spring. Their bodies are so well protected by their smooth, sloping wings that it requires a drenching dose of a strong oil or soap mixture to kill them; when they dropped upon stones or other hard objects, they were easily killed by weaker mixtures.*

The fight against the nymphs or young "hoppers."—As soon as the nymphs began to hatch in the latter part of June in 1902, we turned our insecticidal batteries loose on them. It was soon demonstrated that they could be quickly killed *when hit* with kerosene emulsion, tobacco decoction or whale oil soap at strengths which would not injure the foliage. But it was no easy matter to hit them as they all lived on the under sides of the leaves. This accomplished, it was necessary to devise the most practicable and effective way of making the application on large areas. With horse-power pumps or mechanically-set nozzles on any pumps (Fig. 33), the work could not be done thoroughly enough to pay for the mixture used. To do thorough and effective work against the young " hoppers," it was necessary to stop at each vine and with underspray nozzles (Fig. 36) drench the undersides of all the leaves. In Fig. 35 is shown the outfit with which we sprayed a nine-acre vineyard. On such large areas one of the steam power pumps would have given the necessary pressure to supply the six nozzles much easier and at less expense. It required trained men at the nozzles, as one grower demonstrated when his hired men used about one-third as much spray per acre and killed only one-third as many of the nymphs as our trained college students did. One cannot hurry such a job. *Every " hopper " must be hit* and there are a good many leaves to drench on a grape-vine about July 1st.

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* We visited a large vineyard of the Clinton variety at St. Catherines, Canada, which has been seriously infested with this pest for several years. These Clinton vines threw up many shoots around their base early in the season and the "hoppers" worked on these first. The owner was killing many of the adult "hoppers" by spraying these early shoots with whale oil soap, 2 lbs. in 1 gal. water, making several applications. Later the shoots were broken off and buried, doubtless thus disposing of many eggs. This method would not be applicable to Concords and other varieties that do not develop these shoots freely.

It was about July 10th when we began spraying for the nymphs on a large scale. We used whale oil soap (1 pound in 10 gallons of water) because it was readily obtainable in large quantities from a nearby source (W. H. Owen, Catawba Island, Ohio); it was also easily prepared, and it probably has some fertilizing value. It was recommended for the grape leaf-hopper as early as 1865. It took three to four men and a team four days thoroughly to spray nine acres early in July; they used 350 pounds of the soap. The same vineyard was sprayed again 20 days later and it took over four days and 630 pounds of the soap on account of the greater amount of foliage. About July 25th, another vineyard of six acres was sprayed by two boys, two men, and one horse in three days, using 318 pounds of soap. It cost about $5.00 per acre effectively to spray vineyards once after July 15th. The work should begin at least by July 1st, when there is much less foliage, and it could be done with half the soap and in two-thirds the time it will require two or three weeks later. We used more than a ton of whale oil soap in our experiments in the infested region in 1902. It then cost three cents per pound in 400-pound barrels.

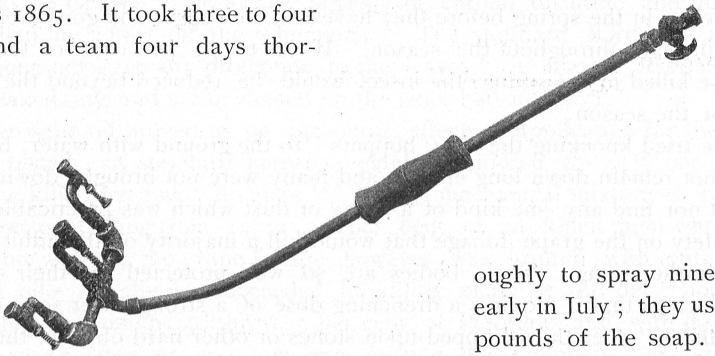

FIG. 36.—*Gould's underspray nozzles for spraying the nymphs in July.*

Thoroughness is the keynote of success in spraying for the young " hoppers." It is waste of time and materials to entrust it to inexperienced hands. The personal work of the college student assistants and ourselves in various infested vineyards where all could see, gave the vineyardists object lessons which will not be forgotten soon, which they could not get from this printed page, and which will save many of them from a useless expenditure of time and money in attempting to combat this insect by only the most thorough work.

Some of the results of the spraying work in Chautauqua county.—In September, the vineyards or parts of vineyards sprayed with the whale oil soap solution for the nymphs in July could be readily distinguished from untreated vineyards as far as one could see them. The sprayed foliage remained green and performed its proper functions of ripening the wood and fruit, while the untreated vines lost their leaves early and thus could not properly ripen the next year's wood and the fruit could not get its full color or sweetness. The difference between sprayed and unsprayed vines is well shown in Fig. 37. The fruit from two of the sprayed vineyards brought $2.00 per ton above the market price, as it was sweeter and riper.

One vineyardist offered his prospective crop of Concords from four acres of badly infested vines in the spring for $25.00, but could find no buyer. We expended less than $10.00 per acre in spraying experiments on the vineyard during the season, and the crop brought nearly $200.00 net after deducting all other expenses. Two acres of Wordens belonging to the same vineyardist and nearly as badly infested which we sprayed only once in July at an expense of less than $5.00 per acre, developed a crop which brought $164.00 net. The sprayed vineyards demonstrated to the most skeptical that the grape leaf-hopper can be controlled by practicable methods.

Notes on other remedial measures.—In 1856, trap-lanterns were recommended to attract and catch the "hoppers," and later writers advised carrying burning torches through the vineyard at night. Some writers have doubted the efficacy of these devices, but there seems to be no records of careful tests. A lantern was set near where thousands of the old hibernated "hoppers" were at work in May, 1902. The catch for one favorable night was only 50 to 75 "hoppers," not a "drop in the bucket." Extensive experiments with trap-lanterns, as detailed in Bulletin No. 202, demonstrated their uselessness as aids in our insect warfare.

The spraying of grass borders, piles of leaves, clumps of grass, and other nearby hibernating places of the adults with crude petroleum or kerosene to kill the hibernating adults in winter or early spring has been suggested. But it would require large quantities of oil to treat such places, and neighboring woodlands, swales, gullies and the like which it would not be practicable to spray, secrete a large proportion of the "hoppers."

It would be feasible, however, to burn over most of the hibernating places of the "hoppers" in winter or early spring, and a light spraying of oil before burning would often facilitate matters, Many thousands of the adults could be destroyed by thus burning wind-swept piles of leaves, bordering strips of grass, weedy ditches, swales or gullies in winter or before April 15th. It is doubtful whether enough "hoppers" could be killed to pay for raking up and burning the comparatively few leaves that remain under the vines during the winter.

The cultivator or plow can also play an important part in the warfare against this pest. One vineyardist, after mowing down the weeds, plowed a double furrow close to his vines late in the fall. In the spring he found very few "hoppers" in the plowed section while they were abundant elsewhere in his vineyard. He believes that thousands of them were buried alive. Every little clump of grass or pile of leaves in the vineyards in May harbors hundreds of the "hoppers" and these could be buried alive by plowing at that time. Undoubtedly late fall or early spring plowing will materially help in controlling the grape leaf-hopper.

Acknowledgments.—To the vineyardists of the infested region, we are indebted for suggestions and kindly coöperation.

Our best thanks are also due to the following manufacturers of spray apparatus and insecticides for placing at our disposal pumps or materials for use in the above experiments : Bowker Insecticide Co., Boston, Mass ; Field Force Pump Co., Elmira, N. Y.; Friend Manufacturing Co., Gasport, N. Y.; Goulds Manufacturing Co., Seneca Falls, N. Y.; Miller Bros., Bergen, N. Y.; The Spramotor Co., Buffalo, N. Y. The aid accorded by these firms greatly facilitated the campaign against the "hoppers."

X. GENERAL RECOMMENDATIONS FOR COMBATING THE INSECT

1. Many of the hibernating adults can be killed by burning grass borders, weedy ditches, swales and brush-grown gullies, and piles of leaves in winter or early spring.

2. Late fall or early spring plowing (before May 1st) in the vineyards will also bury many of them alive.

3. Thousands of the hibernated adult "hoppers" can be caught on sticky shields (Figs. 30 and 32) in early June. Or they may be killed by knocking them to the ground with a whale oil soap spray (1 lb. in 6 or 7 of water) and quickly hitting them there with a kerosene-water spray (25 per cent kerosene) as shown in Fig. 34.

4. The nymphs or young "hoppers" quickly succumb when hit with a spray of whale oil soap (1 lb. to 10 gals. water), a tobacco decoction, or kerosene emulsion. It is necessary to stop at each vine and drench the undersides of the leaves, as shown in Fig. 35. Only the most thorough kind of work will pay ; each nymph must be hit with the spray. Spray early in July. One thorough application, costing less than $5.00 per acre at that time, will often be sufficient for the season. The results of an extensive campaign against the grape leaf-hopper, as shown in Fig. 37, demonstrate that it will amply repay any vineyardist to go to the trouble and expense of fighting this insect.